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THE OBSERVATIONAL ENVIRONMENT OF ASTRONOMICAL SATELLITES AND RELATED SOFTWARE SUBROUTINES

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December 1972

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ABSTRACT

Methods are described for calculating significant factors in the observational environment of orbiting astronomical satellites. These factors must be considered in the process of scheduling observations and in data reduction. Subroutines which perform these calculations are described.

CONTENTS

ILLUSTRATIONS

THE OBSERVATIONAL ENVIRONMENT OF ASTRONOMICAL SATELLITES AND RELATED SOFTWARE SUBROUTINES

Section 1

INTRODUCTION

Astronomical observations made from oribiting satellites are the end product of high cost space astronomy programs. To be cost effective these programs require that the scientific operation of the observatory must be highly efficient and that the resulting data be of highest possible quality, free from the contaminating background effects which are ever present in the orbital observational environment.

The data contaminating backgrounds which most seriously constrain OAO observations are:

1. Background radiation due to the concentration of high energy protons and electrons in the earth bound region known as the South Atlantic Anomaly. The OAO orbit passes directly through this region several times per day. Both OAO-II and OAO-C are seriously contrained by this background loosing about 30% of their total available observing time.

2. Background light which is scattered off the OAO light baffles and enters the telescope optics whenever the spacecraft pointing axis comes close to bright sources such as the sun the moon and the sunlit earth. These scattered light backgrounds consume an additional 30% of the available observing time on OAO.

These background constraints leave only about 30% of the time when the orbital environment is reasonably "clean" for the acquisition of reliable data.

The orbital observational environment is of course a highly dependent function of time. It is a compound function of the relative positions of the sun, the moon, the earth, and orbit of satellite and the position of the satellite in its orbit.

In addition there are other constraints called operational restrictions. These are due to spacecraft thermal and power limitations which prohibit pointing the spacecraft within certain critical regions. These constraints are a function of the position of the sun and the precession of the orbit.

In order to successfully carry out the scientific objectives it is essential that the scheduling of astronomical observations be done efficiently and with care to insure that maximum use is made of the available viewing time and that the data acquired during this time is of highest possible purity. The scheduling of observations and the subsequent reduction of data also must maintain a pace equal to or greater than the maximum observational rates which are controlled by the orbital environmental constraints and the spacecraft operational restrictions.

It is clear that computer software systems must be used to accomplish the above stated requirements. Orbital elements, spacecraft parameters and observational requirements are input to the system. The subroutines described in this report compute the orbital environment as a function of time.

By a sequence of calls to these subroutines the schedule driver assemblies the critical beginning and end times for periods of environmental contamination and constructs a timeline. Other programs then integrate this environmental timeline to accomplish the various tasks needed to schedule observations during periods which conform to the data requirements of a particular observation.

In addition to its value in scheduling orbital observations the environmental timeline is essential to the comprehensive reduction of data. The timeline is an accurate concise minute by minute history of conditions under which the data was acquired. It provides the necessary information required to evaluate the quality or the contamination of the data and it rapidly facilitates the subsequent background corrections. The most effective way to correlate the environment with the data is to input the timeline to the data reduction program. Examples of environmental timeline formats used in OAO scheduling and data reduction programs are shown in Figures 1 and 2.

Section 2

METHODS OF SOLUTION

2.0 General Information

Described in this section are the methods employed in the calculation of the significant factors of the OAO environment. The expressions which follow define the geometry of the orbit both in celestial and geocentric frames, and consequently permit expansion to include factors which have not been considered significant in the past but which, with increasingly sophisticated instruments, may become significant in the near future.

While these methods were developed specifically for the OAO-B spacecraft it has been demonstrated that they are applicable to any circular orbit and have been used to generate a simulated orbit for the proposed IUE satellite which will have a synchronous altitude.

2.1 Position of the Principle Bodies

The positions of the Sun and Moon with respect to the satellite are assumed to be the same as with respect to the Earth. Ephemeris equations that generate Right Ascension and Declination for the Sun and Moon were developed for use in the OAO-B Scheduling System (Reference 1). These equations are functions of time expressed in Julian Day minus 2.438 million. Unit vectors are calculated from R. A. and Dec. using the relationships:

$$u_1 = \cos\alpha \cos\delta$$

$$u_2 = \sin\alpha \cos\delta$$

$$u_3 = \sin\delta$$

where

α is Right ascension

δ is Declination

2.2 Calculation of Occultation Period

The criteria for determining target occultation by the Earth are the same as those used in the ground support programs to command the satellite. Rather than using the true Earth size, a safety region is created by increasing the true angular radius of the Earth by an amount specified as an input. Usually this is about 14 degrees. The total angular radius of the Earth is then:

$$\gamma = \sin^{-1}\left(\frac{R_E}{A}\right) + D$$

where

R_E is the Earth's mean radius

A is the semi-major axis of the OAO orbit

D is the width of the safety region in radians

The calculation of occultation assumes a spherical Earth and a circular orbit.

First, we calculate the time, t_{eo}, corresponding to the nodal passage of the orbit for which the elements are given.

$$t_{eo} = t_e - \frac{\omega_e + M_e}{\rho}$$

where

t_e is the epoch in days

ω_e is the argument of perigee at epoch

M_e is the mean anomaly at epoch

ρ angular motion in radians per day

Then, the number of orbits completed since epoch, an integer, may be found by,

$$N = \frac{t - t_{eo}}{P}$$

t is the present time

$$P = \frac{2\pi}{\rho} \quad \text{period in days}$$

The right ascension of the ascending node is then

$$\Omega = \Omega_e + Nd$$

where

Ω_e is the right ascension of the ascending node at epoch

d is the precession of the node in radians per orbit

Next we must find the azimuth of the vector along the negative boresight axis (the vector from the target to the satellite) projected into the orbital plane.

The x and y direction cosines of the boresight vector in the orbital plane are given by

$$a = \cos \delta_t \cos (\Omega - \alpha_t)$$

and

$$b = \cos i \cos \delta_t \sin (\Omega - \alpha_t) + \sin i \sin \delta_t$$

where

α_t is the right ascension of the target

δ_t is the declination of the target

and

i is the inclination of the orbit.

The azimuth of the negative boresight vector is then:

$$\epsilon = \tan^{-1}\left(\frac{b}{a}\right) + \pi$$

The points of emersion and immersion differ from ϵ by an angle η given by

$$\eta = \cos^{-1}\left[\frac{\cos\gamma}{\sqrt{a^2 + b^2}}\right]$$

where

γ, a and b are defined above.

Thus we have the anomaly at emersion of the target:

$$\beta_r = \epsilon + \eta$$

and at immersion

$$\beta_s = \epsilon - \eta$$

The times corresponding to β_r and β_s are obtained by:

$$t_r = t_{eo} + NP + \beta_r/\rho$$

$$t_s = t_{eo} + NP + \beta_s/\rho$$

where all terms have been previously defined.

A complete mathematical treatment of this problem may be found in Reference 2 from which this solution was derived.

2.3 Calculation of Radiation Level in the South Atlantic Anomaly

When the satellite passes through the South Atlantic Anomaly, the comparatively high-level of background radiation may have a significant effect on the data. For this reason, it would assist the astronomer in analyzing the data, to know approximately what the background flux intensity was when the data was taken. Reference 3 contains world maps of the South Atlantic anomaly derived emprically and displayed parametrically with respect to altitude and threshold energy. For this application, the map of proton flux above 15 MEV for an altitude of 800 KM was used. This map gives three contours corresponding to proton fluxes of 10, 100 and 1000 protons per cm^2 per sec. Each of the three contours was fit with a polygon. If the latitude and longitude of the sub-satellite point are known, it may be determined whether the point lies inside any of the contours.

Determination of the sub-satellite point begins with the calculation of satellite position in celestial coordinates. The right ascension of the ascending node is given by:

$$\Omega = \Omega_e + (t - t_e)\ d$$

where

Ω_e is the right ascension of the ascending node at epoch.

t_e is the epoch of the orbital elements in days

t is present time in days

and d is precession of the node in radians/day.

The azimuth of the satellite position measured from the ascending node is:

$$A = \omega_e + M_e + (t - t_e)\rho$$

where

ω_e is the argument of perigee at epoch

M_e is the mean anomaly at epoch

ρ is the angular motion in radians per day

t and t_e as above.

The declination may now be obtained from:

$$\delta = \sin^{-1} \left(\frac{\sin A}{\sin i} \right)$$

in which i is the orbital inclination.

Transforming back to the equatorial plane from the orbital plane the satellite azimuth from the node is

$$A_t = \tan^{-1} \frac{\tan \delta}{\tan i} \Big/ \frac{\cos A}{\cos \delta}$$

and the right ascension of the satellite is:

$$\alpha = \Omega + A_t$$

The latitude of the sub-satellite point is equal to the declination, so we have $\emptyset = \delta$.

To calculate the longitude, we make use of an ephemeris equation which yields Greenwich Siderial Time as a function of Greenwich Mean Time, or:

$$t_s = f(t)$$

Since GST is by definition the right ascension of the Greenwich Meridian, the satellite longitude, Θ, is:

$$\Theta = \alpha - t_s$$

The sub-satellite point (Θ, $\emptyset$) may now be compared with the contours to find the approximate proton flux. The solution was derived from work done on the OAO-B Scheduling System (Reference 1).

2.4 Calculation of Percent of Visible Earth Illuminated by Sunlight

It is useful to the astronomer analyzing the data to know what percent of the Earth which is visible from the spacecraft is illuminated by the sun. Subroutine PELS which performs this calculation is available from the OAO Spacecraft Control Programming Section (NASA Code 542) and the mathematical analysis is described in detail in Reference 4. This routine was developed for use in the OAO-B Scheduling System (Reference 1).

2.5 Calculation of Angular Distance to Nearest Illuminated Point of Earth

In order to evaluate the effects of an illuminated Earth on the data, the astronomer must know the angle between the experiment boresight and the illumination source. Since the Earth subtends over one-fourth of the total solid angle as seen from the spacecraft, the most meaningful quantity to calculate would be the nearest lit point. This calculation is performed by Subroutine DTSE which is available from OAO Spacecraft Control Programming Section (NASA Code 542). The documentation for this subroutine was not yet available at the time of writing, however, the analysis may be obtained from the same source as Reference 4.

Section 3

DESCRIPTION OF SUBROUTINES

3.0 General Information

The four routines described in this section form a package which may be incorporated into the driver of scheduling or data reduction system to accurately simulate the OAO environment as a function of time.

It is important to preserve the order of execution of these routines because certain intermediate quantities are generated in one routine and passed through the program interface to another. In general OCCULT should be executed first to read in orbital data and then for each time element of the simulation OCCULT should be executed first, then ANMLY followed by PELS and DTSE the latter two which may interchanged.

3.1 Subroutine ANMLY Functional Description

Subroutine ANMLY generates an estimate of the radiation level experienced by the satellite as it passes through the South Atlantic anomaly. This is done by calculating the latitude and longitude of the sub-satellite point using the method described in Paragraph 2.3 and then testing to see whether the point lies within any of three map contours of the anomaly area.

The map contours represent boundaries of regions where proton radiation exceeds 10, 100 and 1000 protons/cm^2/sec. These particular levels were selected for OAO-B and can be easily re-defined for any other satellite.

A single integer is set to zero if the sub-satellite point is not within any of the contours, and is set to 1, 2 or 3 if the point lies within the 10, 100 or 1000 proton/cm^2/sec. contour respectively. This integer then is approximately equal to $\log_{10}$ F where F is the proton flux.

A call to subroutine OCCULT must be executed prior to calling ANMLY because OCCULT reads the orbital elements from a disk dataset and calculates several quantities used by ANMLY.

Also, ANMLY must be executed prior to calling PELS or DTSE for each simulation time element because ANMLY generates the satellite position direction cosines used by those subroutines.

Subroutine ANMLY may be easily modified to estimate cosmic ray flux as a function of magnetic latitude which can be generated from the latitude and longitude of the sub-satellite point.

Program Interface

Calling sequence:

CALL ANMLY (AJID, NOM)

Input Items:

AJID	Julian Day of digital group being processed.
TO	(common) ratio of earth radius to orbital semi-major axis.
EJD	(common) Julian Day of epoch of orbital elements.
DEGDAY	(common) orbital precession of node in degrees/day.
ANODE	(common) Right Ascension of ascending node at epoch.
ANGE	(common) sum of the mean anomaly at epoch and the argument of perigee at epoch.
TPP	(common) angular motion in radians/day.
FINC	(common) orbital inclination in radians.

Output Items:

NOM — approximate integer value of log base 10 of proton flux.

PSAT — (common) direction cosines of satellite position in inertial coordinates.

Common Blocks Referenced:

COMOCL

3.2 Subroutine OCCULT Functional Description

Subroutine OCCULT is a modified version of Subroutine OCTIM of the OAO-B Scheduling System (Reference 1). Subroutine OCCULT calculates the positions of the sun and moon and computes the times of emersion and immersion of occultations of the target by the earth (see Paragraphs 2.1 and 2.2).

It is interesting to note that the capability readily exists for inclusion of a correction for wavelength aberration due to motion of the spacecraft normal to pointing axis since all of the orbital parameters are present.

The first call to OCCULT reads the orbital elements dataset and computes the earth's angular radius, the Julian Day of Epoch and the orbital period.

Subsequent calls to OCCULT return the rise and set times of the target for a specified orbit number and target position. An alternate entry point, OCCTIM, is provided which is entered with Julian Day rather than orbit number, the latter being calculated upon entry.

Entry point OCNOD returns the time of nodal passage in Julian Days for a specified orbit number.

The OCCULT and OCCTIM entries have an intermediate results print flag in the argument list which if greater than zero, causes a minute-by-minute timeline plot of the orbit showing the unocculted intervals by the letter 'U' and the occulted portions with a dash.

Program Interface

Calling sequence:

```
CALL OCCULT (NORB, RISE, SET, RAS, DECS, LMN, ANAME)
CALL OCCTIM (AJID, RISE, SET, RAS, DECS, LMN, ANAME)
CALL OC NOD (NORB, TIM)
```

Input Items:

NORB	orbit number.
RAS	Right Ascension of target in radians.
DECS	declination of target in radians.
LMN	intermediate printout flag.
ANAME	starname
AJID	current time in Julian Days.

Orbital elements and principal body sizes read from permanent disk dataset (see Section on Program Inputs).

Output items:

RISE	Julian Day of target emersion from occultation by earth.
SET	Julian Day of target immersion behind earth.
ANJD	(common) Julian Day of nodnal passage.
TPP	(common) angular motion in radians per day.
EJD	(common) Julian Day of Epoch.
USUN	(common) direction cosines of sun position.

Subroutine called:

JDAY

TIME (see DATE)

Common blocks referenced:

COMOCL

3.3 Subroutine PELS Functional Description

Subroutine PELS was developed for OAO-B with the help of the Spacecraft Control Programming Section NASA Code 514 (see Reference 4). PELS calculates the percentage of the earth, as seen from the spacecraft, which is lit by the sun.

Program Interface

Calling sequence:

CALL PELS (USUN, PSAT, A, B, TOL, IPR)

Input Items:

USUN unit vector to sun in inertial coordinates.

PSAT position vector of satellite with respect to the earth in units of earth radii.

TOL graying tolerance in radians used to handle quadrature cases where circular functions are badly behaved, for this application set to .001.

IPR intermediate printout flag; 1-no printout, 0-print out arguments only, -1- full debug printout.

Output items:

A solid angle in steradians subtended at satellite by sunlit earth.

B A expressed as percentage of solid angle of full earth.

Subroutines called:

DQSF (Scientific Subroutine Package)

3.4 Subroutine DTSE Functional Description

Subroutine DTSE was developed for OAO-B with the help of the Spacecraft Control Programming Section NASA Code 514. DTSE calculates the angular distance from the spacecraft boresight axis to the nearest sunlit point of earth.

Program Interface

Calling sequence:

CALL DTSE (USUN, PSAT, ATUDE, DST, IPR)

Input items:

USUN	unit vector to sun in inertial coordinates.
PSAT	position vector of satellite with respect to earth in units of earth radii.
ATUDE	unit vector of spacecraft boresight in inertial coordinates.
IPR	intermediate printout flag; -1 no printout; 0 arguments only; 1 partial debug printout; 2 full debug printout.

Output items:

DST	angular distance in radians from boresight to nearest sunlit point of earth.

Subroutines called:

CROSS	SINSLV
DOT	F
NORM	DRTMI (SSP)

3.5 FUNCTION JDAY Functional Description

Function JDAY returns integer Julian Day from the month, day of month and year or from the day of year and year.

Program Interface

Calling Sequences:

J = JDAY (ID, IM, IYR) or J = JDAY (IDY, IONE, IYR)

Input Items:

ID, IM, IYR	day of month, month, and year minus 1900.
IDY	day of year.
IONE	integer variable containing the integer value 1.

Output items:

J	integer variable into which integer Julian Day is to be stored.

3.6 Subroutine TIME Functional Description

Subroutine TIME converts floating point Julian Day into calendar date and time in hours, minutes and seconds. Day of year is also calculated for convenience.

Program Interface

Calling Sequence:

CALL TIME (AJID, ID, IM, IY, IGDAY, IHR, IMIN, ISEC)

Input Items:

AJID	Julian Day to be converted

Output Items:

ID, IM, IY, IGDAY, IHR, IMIN, ISEC - day of month, month, year minus 1900, day of year, hour, minute and second corresponding to Julian Day AJID.

REFERENCES

1. OAO-B Scheduling System - Source Listings and Working papers; Dr. D. West, NASA/GSFC Code 672; E. M. Greville, CSC.

2. Mathematical Analysis for the Orientation and Control of the OAO Satellite; P. B. Davenport, January 1963, NASA TN D-1668.

3. World Maps of Constant B. L. and Flux Contours; E. Stassinopoulos, 1970; NASA Office of Technology Utilization SP-3054.

4. Mathematical Analysis for PELS: R. Des Jardins, June 1971; OAO/SCPS (NASA Code 514) Technical Memorandum, T-71-5.

TIME			ENVIRONMENT	EVENT	
340d	18h	45m	ORBIT 185BEGINS	SUN OCL	100%
340	18	46		SUN OCL	100%
340	18	47		SUN OCL	100%
340	18	48		SUN OCL	100%
340	18	49		SUN OCL	100%
340	18	50		SUN OCL	100%
340	18	51		SUN OCL	100%
340	18	52		SUN OCL	100%
340	18	53		SUN OCL	100%
340	18	54		SUN OCL	100%
340	18	55		SUN OCL	100%
340	18	56		SUN OCL	100%
340	18	57		SUN OCL	100%
340	18	58	CONTACT 185R BEGINS	SUN OCL ROS	100%
340	18	59	RISE OF 223640	SUN OCL ROS	100%
340	19	0		SUN ROS	100%
340	19	1		SUN ROS	100%
340	19	2		SUN ROS	100%
340	19	3		SUN ROS	100%
340	19	4		SUN ROS	100%
340	19	5		SUN ROS	100%
340	19	6		SUN ROS	94%
340	19	7		SUN ROS	86%
340	19	8		SUN ROS	81%
340	19	9		SUN	77%
340	19	10		SUN	73%
340	19	11		SUN	70%
340	19	12		SUN	66%
340	19	13		SUN	63%
340	19	14		SUN	60%
340	19	15		SUN	57%
340	19	16		SUN	43%
340	19	17		SUN	40%
340	19	18		SUN	36%
340	19	19		SUN	33%
340	19	20		SUN	30%
340	19	21		SUN	27%
340	19	22		SUN	23%
340	19	23		SUN	19%
340	19	24	DAYLIGHT ENDS	SUN	14%
340	19	25			8%
340	19	26			0%
340	19	27	OBSRV OF 223640 START	EXP	0%
340	19	28	OBSPARM 85 (100000 0-412 2232 32.2	EXP	0%
340	19	29	IRU UPDT	EXP	0%
340	19	30		EXP	0%
340	19	31		EXP	0%
340	19	32		EXP AN1	0%
340	19	33		EXP AN1	0%
340	19	34	OBSRV OF 223640 COMPLETE	EXP AN1	0%
340	19	35	SLEW TO 000315 START	SLU AN2	0%
340	19	36		SLU AN2	0%
340	19	37	CONTACT 185M BEGINS	MAD SLU AN2	0%
340	19	38		MAD SLU AN2	0%
340	19	39		MAD SLU AN1	0%
340	19	40		MAD SLU AN1	0%

OCCULTATION OF TARGET

SPACECRAFT IN SUNLIGHT

PERCENT OF EARTH SUNLIT

RADIATION IN SOUTH ATLANTIC ANOMALY

Figure 1. Example of Utilization of Environmental Data in Observation Scheduling

* * * EXPLANATION OF SYMBOLS * * *

SEQ: READOUT SEQUENCE NUMBER

S: EXPERIMENTER STAR PRESENT N-NO, Y-YES

O: OCCULTATION OF TARGET BY OVERSIZED EARTH

JULIAN DAY: ASTRONOMICAL JULIAN DAY MINUS 2.44 MILLION

ERROR: FIGURE OF DATA QUALITY FOR EACH WORD ON A SCALE OF 1 TO 7 WHERE ONE IS PERFECT

R: RADIATION FROM SOUTH ATLANTIC ANOMALY IN LOG10 OF PROTONS PER SQCM PER SEC ABOVE 15 MEV

PEL: PERCENT OF EARTH ILLUMINATED BY SUN AS SEEN FROM SPACECRAFT

DST: ANGULAR DISTANCE IN DEGREES FROM BORESIGHT TO NEAREST SUNLIT POINT OF EARTH

X: CARRIAGE NOT IN STANDARD ROUTINE OR IN RETRACE 1-CAR 1, 2-CAR 2, 3-BOTH

SLIT ANGLE: ORIENTATION OF SLIT MEASURED COUNTER-CLOCKWISE FROM HORIZONTAL

*** SCIENTIFIC DATA AND OBSERVATIONAL ENVIRONMENT FACTORS ***

*** SLIT ANGLE:-122 DEG *** POWER: 0 PERCENT *** BORESIGHT-SUN DISTANCE: 94 DEG *** BORESIGHT-MOON DISTANCE: 73 DEG ***

*** TIME				*** UNCORRECTED COUNTS PER 14 SECONDS						***	WAVELENGTH				*** QUALITY FACTORS ***						
SEQ	DAY	GMT	JULIAN DAY	U2	V3	V3	V1	U3	V2	U1	U1	V1	U2	V2	ERROR	S	O	R	DST	PEL	X
20	355	0: 5:27	941.50379	24	128	96	0	0	112	6	705.35	1636.43	1411.12	2804.70	6666666	N	O	2	OCC	0	0
21	355	0: 5:43	941.50397	16	128	128	32	0	112	4	705.35	1636.43	1411.12	2804.70	6666666	N	O	2	OCC	0	0
22	355	0: 5:58	941.50415	32	160	160	32	0	144	4	705.35	1636.43	1411.12	2804.70	6666666	N	O	2	OCC	0	0
23	355	0: 6:14	941.50433	24	96	128	32	0	96	20	705.35	1636.43	1411.12	2804.70	6666666	N	O	2	OCC	0	0
24	355	0: 6:30	941.50452	16	128	128	32	0	112	12	705.35	1636.43	1411.12	2804.70	6666666	N	O	2	OCC	0	0
25	355	0: 6:45	941.50470	40	160	128	0	0	96	6	705.35	1636.43	1411.12	2804.70	6666666	N	O	2	OCC	0	0
26	355	0: 7: 1	941.50488	16	128	128	32	0	144	12	705.35	1636.43	1411.12	2804.70	6666666	N	O	2	OCC	0	0
27	355	0: 7:17	941.50506	40	608	640	32	0	128	20	705.35	1636.43	1411.12	2804.70	6666666	N	O	2	59	0	0
28	355	0: 7:33	941.50525	24	3776	3776	32	0	224	6	705.35	1636.43	1411.12	2804.70	6666666	N	O	2	57	0	0
29	355	0: 7:48	941.50543	24	4480	4448	32	0	240	8	705.35	1636.43	1411.12	2804.70	6666666	N	O	1	56	0	0
30	355	0: 8: 4	941.50561	32	4864	4864	32	0	208	4	705.35	1636.43	1411.12	2804.70	6666666	N	O	1	54	0	0
31	355	0: 8:20	941.50579	24	5120	5152	32	0	240	10	705.35	1636.43	1411.12	2804.70	6666666	Y	O	1	53	0	0
32	355	0: 8:36	941.50597	24	5184	5184	32	32	240	6	705.35	1636.43	1411.11	2804.68	6666666	N	O	1	51	0	0
33	355	0: 8:51	941.50616	16	5216	5216	32	0	304	10	705.35	1636.43	1410.95	2804.35	6666666	N	O	1	50	0	0
34	355	0: 9: 7	941.50634	16	5216	5216	32	0	400	14	705.35	1636.43	1410.79	2804.03	6666666	N	O	1	48	0	0
35	355	0: 9:23	941.50652	32	5376	5344	0	0	1424	10	705.35	1636.43	1410.63	2803.71	6666666	N	O	1	47	0	0
36	355	0: 9:38	941.50670	16	5344	5376	32	0	106464	10	705.35	1636.43	1410.46	2803.38	6666666	N	O	1	46	1	0
37	355	0: 9:54	941.50688	32	5248	5216	32	0	592	20	705.35	1636.43	1410.30	2803.06	6666666	N	O	1	44	1	0
38	355	0:10:10	941.50707	16	5280	5280	32	0	336	6	705.35	1636.43	1410.14	2802.74	6666666	N	O	1	43	1	0
39	355	0:10:26	941.50725	16	5280	5312	32	0	320	10	705.35	1636.43	1409.98	2802.42	6666666	N	O	1	42	1	0
40	355	0:10:41	941.50743	16	5184	5184	32	0	288	4	705.35	1636.43	1409.82	2802.09	6666666	N	O	1	41	1	0
41	355	0:10:57	941.50761	24	5216	5184	32	0	208	10	705.35	1636.43	1409.65	2801.77	6666666	N	O		40	1	0
42	355	0:11:13	941.50779	16	5216	5216	32	0	224	10	705.35	1636.43	1409.50	2801.45	6666666	N	O		38	2	0
43	355	0:11:29	941.50798	24	5248	5248	32	0	176	6	705.35	1636.43	1409.34	2801.13	6666666	N	O		37	2	0

Figure 2. Example of Utilization of Environmental Data in Data Reduction